CONTRIBUTION OF STEEL FIBER IN A SMALL SCALE REINFORCED CONCRETE BEAM

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ABSTRACT

Since today, fiber reinforced concrete is one of the most realistic materials to develop the use of concrete in load-bearing structure. The hooked-end steel fiber with two different the aspect ratio were used in this study. They are 65 mm aspect ratio with 0.55mm in diameter and 35 mm in length and 0.75 mm in diameter, 60 mm in length with 80 mm in aspect ratio. The volume fraction for both of steel fiber used is 1%. There are four concrete batches and each of batches consists of 3 beam specimens with dimension 750 mm x150 mm x150 mm and 6 cube specimens with 150 mm x 150 mm x 150 mm dimension. The beams were tested at 28 days under two-point load. The result showed that the addition of steel fiber in concrete improved the first cracking load, ultimate load, and ductility of the concrete beam. In comparison in terms of concrete compressive strength, SF35 improved for 12.94% and SF60 improved for 26.51% at 7days. Meanwhile, the compressive strength improved for 14.15% and 23.58% at 28 days for SF35 and SF60, respectively. The first crack (Pcr) was determined for the result obtained in experimental and SFRC showed significant increases to first crack load over conventional reinforced concrete beam. The SFRC beam with SF35 increased for 56.33% and SF60 for 68.67% for ultimate load (Pu), when compared to conventional reinforced concrete beam. This shows that longest SF was effective in resisting beam ultimate load compared with shortest SF.

ABSTRAK

Pada masa sekarang, serat konkrit bertetulang merupakan salah satu bahan yang paling realistik untuk membangunkan penggunaan konkrit dalam struktur menanggung beban. Gentian keluli ketagih akhir dengan dua berbeza nisbah aspek yang telah digunakan dalam kajian ini. Mereka adalah 65 nisbah aspek mm dengan 0.55mm diameter dan 35 mm panjang dan 0,75 mm, 60 mm panjang dengan 80 mm dalam nisbah aspek. Pecahan jumlah untuk kedua-dua serat keluli yang digunakan adalah 1%. Terdapat empat kumpulan konkrit dan setiap kumpulan terdiri daripada 3 spesimen rasuk dengan dimensi 750 mm x 150 mm x 150 mm dan 6 spesimen kiub dengan 150 mm x 150 mm x 150 mm dimensi. Rasuk diuji pada 28 hari di bawah beban dua mata. Hasilnya menunjukkan bahawa penambahan gentian keluli dalam konkrit bertambah beban pertama retak, beban muktamad, dan kemuluran rasuk konkrit. Sebagai perbandingan dari segi kekuatan mampatan konkrit, SF35 baik untuk 12,94% dan SF60 baik untuk 26,51% pada 7days. Sementara itu, kekuatan mampatan yang lebih baik untuk 14,15% dan 23,58% pada 28 hari untuk SF35 SF60 dan masing-masing. Keputusan retak pertama (PCR) telah diperolehi melalui eksperimen dan SFRC mengalami kenaikan signifikan kepada beban retak pertama ke atas konkrit bertetulang konvensional rasuk. SFRC rasuk dengan SF35 meningkat untuk 56,33% dan 68,67 untuk SF60% untuk beban muktamad (Pu), berbanding konvensional rasuk konkrit bertetulang. Ini menunjukkan bahawa paling lama SF berkesan dalam melawan beban muktamad rasuk berbanding singkat SF.

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LIST OF ABBREVIATIONS

SFRC	Steel Fiber Reinforced concrete
LI	Literature Review
AR	Aspect Ratio
SF	Steel Fiber
RI	Reinforcement Index

LIST OF SYMBOL

Pcr	First crack
Pu	Ultimate load
fcu	Compressive strength
L	Length
D	Diameter
L/D	Aspect ratio

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays, the application of fiber reinforcement in concrete is not new.There are many researchers focused on fiber application. The fiber can be made from either natural material (asbestos, sisal and cellulose) or a manufactured product such as glass, steel, carbon and polymer (Guneyisi. E. et al., 2013). Among the various types of fibers, steel fiber is the most commonly used for most structural and non-structural purposes (Bolat,H et al,2014).In this research steel fiber have been used. The application of the steel fiber is mostly utilised in construction due to its ability in resisting the formation and growing of cracking, abrasion and enhances the flexural strength, fatigue strength of reinforced concrete (Altun. F. et al,, 2012). From the study, the tensile and flexural strength of concrete enhanced significantly due to addition of steel fiber(Shahiron.S.,2009).

In this study, the behaviour of reinforced concrete beam with different aspect ratio of steel fiber added into mixture were focused. According to the ACI 544, 3R-08, aspect ratio is referred to the ratio of fiber length over the diameter. Normal range of aspect ratio for steel fiber is from 20-100mm. Aspect ratio of steel fiber greater than

100mm is not recommended because it will cause inadequate workability, formation of mat in the mix and also non uniform distributed

1.2 PROBLEM STATEMENT

The properties of the concrete in brittle material which is low in tensile strength and low in strain capacity. Low tensile strength and low strain at fracture were major deficiencies in plain concrete (Suguna. K. et al., 2015). The low tensile strength was attributed to numerous micro cracks in plain concrete. The rapid propagation at these cracks under applied stress was responsible for low tensile strength and brittle failure of material.

In structural application, the concrete will provide the reinforcing bars to carry the tensile force once the concrete has cracked, so that it remains largely in compression under load. As mentioned earlier, tensile failure strain of the reinforced concrete is significantly lower than the yield strain of the steel reinforced and the concrete crack before any significant load to transfer to the steel. In industry application, the steel reinforced needed to carry the tension forces in the concrete.

According to the problem of steel reinforced concrete in structural application and needed in industry application, a new application of reinforced concrete need to develop. So, from the previous research additional fiber is one of the methods to improve the mechanical properties of the structural concrete. According to M. Behloul, 2008, fiber reinforced concrete is one of these new materials ways for concrete structure. Because of that, in this study focused on the contribution of the steel fiber in mechanical properties of the reinforced concrete beam and the effect of aspect ratio the steel fiber in structural behaviour also was investigated.

1.3 RESEARCH OBJECTIVE

The objectives of this research are:

i. To determine the contribution of steel fiber in reinforced concrete beam under flexural load.
ii. To study the effect of fiber aspect ratio to the structural behaviour of reinforced concrete beam.

1.4 SCOPE OF STUDY

The scope of study for this research includes:

i. Type of fiber :

   Steel fiber with aspect ratio, *l/d* 80 mm and 65 mm

ii. Volume fraction, V_f = 1 %
iii. Concrete grade = 25 Mpa
iv. Type of specimens:
   I. Cube specimen = (width x breadth x height)
      = (150 mm x 150 mm 150 mm)
   II. Beam specimen = (length x width x height)
      = (750 mm x 150 mm x 150 mm)

1.5 RESEARCH SIGNIFICANCE

Numerous researches have been performed on mechanical properties of fiber concrete and concrete structural member with fiber under various loading. So, the study of the behaviour to the reinforced concrete beam with steel fiber was studies. In the present investigation, the influence the aspect ratio of steel fiber on strength and flexural behaviour of concrete beam were studies.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the characteristics of steel fiber are discussed and assists with its application. The application of fiber widely used in construction, by adding the fiber in concrete. Reffering to the previous studies, the fibers can improve the mechanical and ductility of concrete, reduced the plastic shrinkage and improve the abrasion. It is proven by Mirzac.F, (1996) the Polypropylene fiber reinforced concrete (PPFRC) not increase the strength of concrete but can improve its ductility, toughness and impact resistance. Rana.A,(2013) also mentioned in his studies that the steel fiber used in concrete to control cracking due to both of drying shrinkage and plastic shrinkage. Then the fibers also reduce the permeability of concrete and thus reduce bleeding of water.

Among types of fibers such as glass, natural and synthetic polymer, the focus given on steel fiber because it is used in this research. The reason using the steel fiber because it can improve the durability of concrete and increase the impact resistance of concrete. Then,the steel fiber having a various types with different properties. The properties of steel fiber have discussed more in this chapter.

2.2 HISTORICAL DEVELOPMENT

Historically, the steel fiber are commonly used since 1980 in united states, Japan and Europe. The steel fiber have proven track record and has been used for a decade to economically toughness concrete floor and precast. Today the steel fibers are major application to industrial in the world. In addition the other major application of steel fiber includes shortcrete and precast element. In Malaysia, the applications of steel fiber are not widely used in industry. So, the researchers of steel fiber reinforced concrete in Malaysia are needed for the further application

2.3 STEEL FIBER CHARCTERISTIC

Generally due to the application of steel fiber in construction, there is a lot of research about the properties of steel fiber in normal concrete. From the previous study there are various types of steel fiber and have their own characteristics. Because of this, the committee member from concrete society has been done the research about the fiber and the steel fiber is one of it. From their research, a standard and the design guide for world application**.** According to the technical report *Fibers as structural element for the reinforced of concrete* and previous study, there indicated that the properties of steel fiber are necessary to define and it also need for experiment work purpose. The characteristics of the steel fiber divided into two parts, there are mechanical properties and physical properties.

2.3.1 Mechanical Properties

Table 2.1: Mechanical Properties of Steel fiber

Steel fiber (Hooked end)	Density	7.85g/cm3
	Modulus of elasticity	205 GPa
	Poison Ratio	0.29
	Yield strength	12.75 MPa
	Tensile strength	1100 MPa

Source: S. Shahidan, 2009

The mechanical properties of steel fiber including the density,modulus elasticity, yields strength and tensile strength. There are various type of steel fiber but based on the previous study, almost the researcher using the steel fiber with hooked end.This is due to its mechanical properties more give a good performance than the other. It is proved by Altun.F. et al., 2006. Based on the LI from other research, it can conclude that the mechanical properties of steel fiber (hooked end) shown at table 3.1(S.Shahidan, 2009). According to the table 3.1, it indicated that the mechanical properties of steel fiber for all types steel fiber. From the table, the modulus of elasticity of steel fiber as higher and it will similarly to the steel reinforcement. However, the yield strength of steel fiber can assist the concrete bonding during cracking propagation. It cause of the high value of the yield strength for steel fiber.

2.3.2 Physical Properties

Regarding to the technical manual, steel fiber are supplied in many different type of shapes as shown in figure 2.1.Regarding to S.Shahidan, 2009, steel fiber have a greater tensile strength than traditional fabric reinforcement and it significantly greater surface area to develop bond with the concrete matrix. Some of the physical characteristics of steel fiber affect on the concrete performance. The reasons are considered to be influenced on the performance of the concrete are the anchorage

mechanism (e.g, deformed shape or hooked end) fiber length, diameter and volume fraction added into the concrete.

According to Altun.F,2012, the fiber length types hooked end are reduced the severity of the failure mode which can change from a brittle shear into a ductile flexure failure, the volume fraction of steel fiber also nfluence the improving strength and ductility of the concrete. Futhermore, the length of steel fiber also taking into account to develop the ultimate strength of it. However, from the few studies on LI, one can successfully enchance the flexural toughness of steel fiber reinforced concrete are by using the large aspect ratio of steel fiber. Many research have been done show the evidence that aspect ratio in concrete performance. The detail explanation about the behaviour of steel fiber will be more discussed in this chapter.

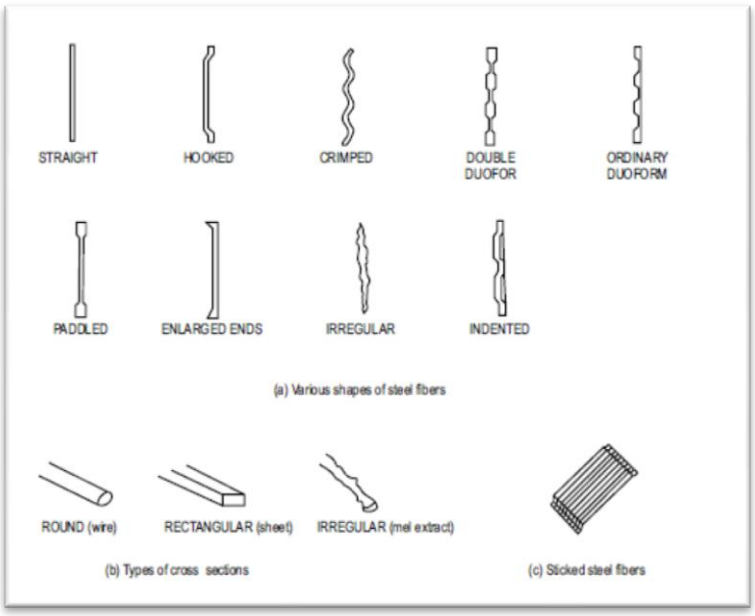

Figure 2.1: Different forms steel fiber

Source: Technical manual of fibers

2.4 MECHANICAL PROPERTIES OF SFRC

The behaviour of the steel fiber reinforced concrete under compression, flexural strength, physical properties and tensile strength will be discussed in this topic. Review from the previous studies, the volume fraction of steel fiber effect the behaviour of concrete. It is proven by Yazici.S. et al., 2006, that in steel fiber reinforced concrete (SFRC) the most important factor affecting the concrete properties are *l/d* ratio and V_f of fibers. Aspect Ratio (AR) is the ratio of fiber length against the diameter (I/d). The higher the AR and volume concentration of the fiber, the better is the performance with respect to the flexural strength, flexural fatigue, toughness, abrasion, impact and crack resistance.

2.4.1 Compressive Strength

From the previous research, by adding the steel fiber to the mixture, the compressive will increase. According to Yazici.S et.al the length of the steel fiber effect the compressive strength. When the *l/d* is 45mm, the compressive strength is 53.7 MPa and for the 65mm is 58.3 MPa. The steel fiber also proved that effect the compressive strength when Nguyen.V.C state in his investigation that, even in members which contain conventional reinforcement in addition to the steel fiber, the fibers have effect on the compressive of concrete. Then, when the steel fiber added into mixture of reinforced concrete beam, it improves the performance of compressive of the structure. (Altun.F. et al., 2012).The Volume of fiber also effect the performance of the concrete in compressive.

Based on investigation by Nguyen.V.C,(2012) the increase of the fiber content the peak of stress-strain curve is increase.(Refer Figure 2.2).Referring to the figure 2.2, the addition of SF can increase the strain at peak load and more reproducible descending branch. Besides that, the SFRC also can absorb much more energy before start to failure compare the plain concrete. The test result by Nagakar ,(1987) indicated that the compression strength increase by addition of SF in plain concrete which is the strength increase 13%- 40% for fibrous concrete.

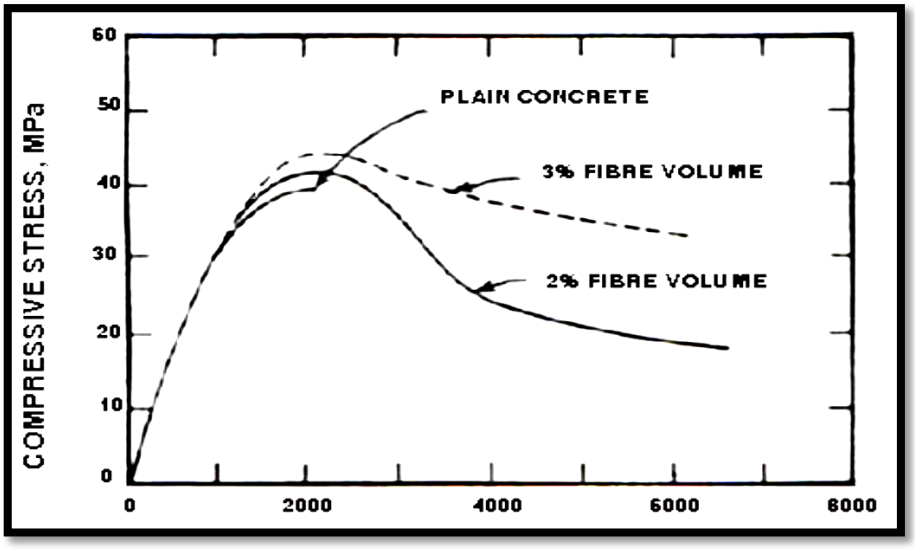

Figure 2.2: Stress-Strain curve

Source: Nguyen.V.C,

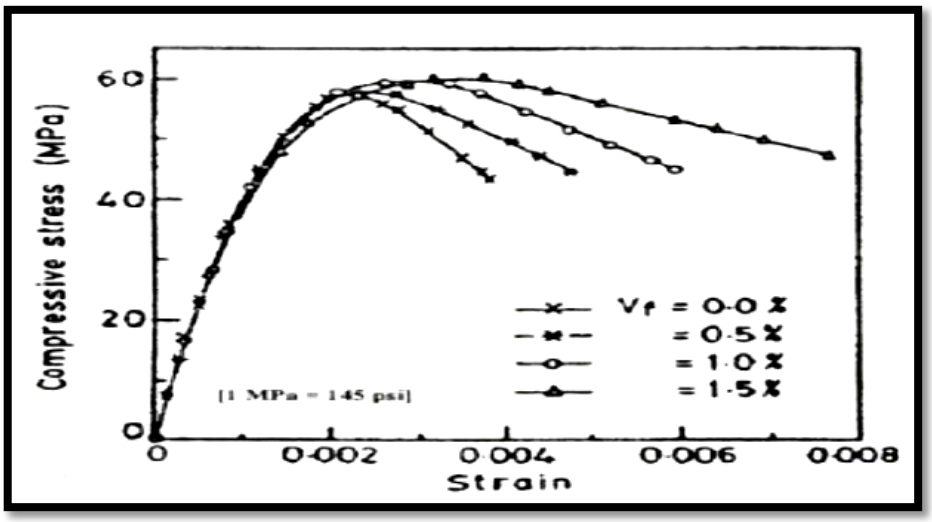

Figure 2.3: Compressive stress versus strain curve

Source: A. Hossein et.al (2012)

The effect of addition SF in compressive behaviour also studied by Hossein.A, 2012. Based on the authors, normal concrete with the high compressive strength usually show more brittle behaviour. For small amount of fiber add to concrete, the compressive strength in concrete does not significantly improve. However, post cracking ductility of the composite may be improved with the addition of steel fiber. From the result obtained by the author which is shown at figure 2.3, it can seen that the volume fraction of steel fiber influence the compressive stress of concrete.

Then, based on the previous research, Naaman, 1987, the strength and toughness of the composite were found to increase the higher loading based on the aspect ratio. Besides that, the shape of steel fiber such as deformed fiber and hooked end will to provide the good energy absorption. The result shows that the concrete improved in 60% from the plain concrete.

2.4.2 Flexural Strength

The behaviour under flexural is the most important aspect ratio for steel fiber, because the practical application is subjected some kind of bending load. Based on previous research by Mohammadi, 2008, according to his testing result, maximum strength are increased in static flexural strength for concrete.The result obtained as shown in figure 2.4, the maximum increase in ultimate load deflection of 61%, 95% and 167% concrete specimen when having length 100 long fiber for 1.0%, 1.5% and 20% fiber respectively.

Maximum flexural loads, first crack loads and corresponding deflections

Fibre mix proportion by weight		Fibre volume fraction (%)	Maximum flexural load and corresponding deflection		First crack load and corresponding deflection	
50 mm long fibres (%)	25 mm long fibres (%)		Deflection (mm)*	Load (kN)*	Deflection (mm)*	Load (kN)*
0	0	0	0.338	11.88	0.338	11.88
100	0	1.0	0.545	16.68	0.397	13.76
65	35	1.0	0.498	16.92	0.396	14.49
50	50	1.0	0.526	16.56	0.385	14.38
35	65	1.0	0.506	16.64	0.392	14.38
0	100	1.0	0.434	15.92	0.401	14.92
100	0	1.5	0.661	20.98	0.399	15.19
65	35	1.5	0.650	20.12	0.401	15.35
50	50	1.5	0.653	18.75	0.399	15.00
35	65	1.5	0.588	17.73	0.394	15.55
0	100	1.5	0.495	17.17	0.399	15.85
100	0	2.0	0.902	23.83	0.405	15.89
65	35	2.0	0.720	22.32	0.405	16.28
50	50	2.0	0.768	19.81	0.402	16.35
35	65	2.0	0.613	18.75	0.408	16.83
0	100	2.0	0.483	18.01	0.401	17.66

* Average of three batches

Figure 2.4: Maximum flexural test plain concrete and SFRC

Source: Mohammadi et al. (2008)

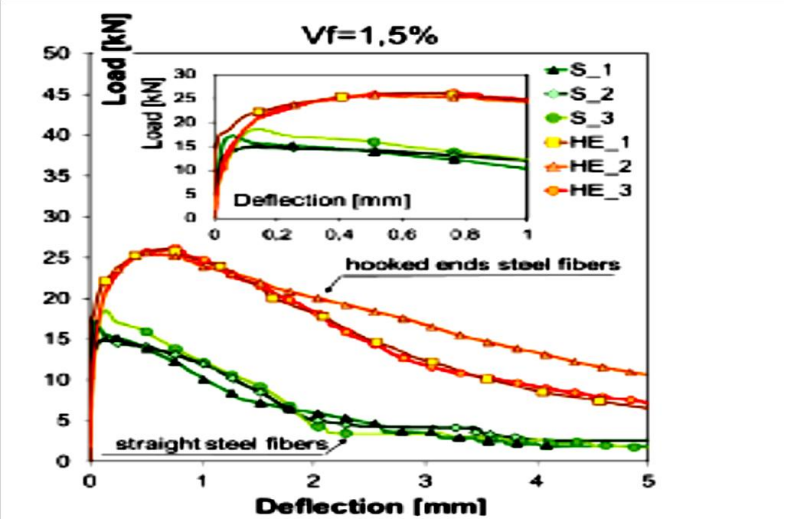

Figure 2.5: Result Load-deflection

Source: Pajak.M. et al. (2013)

Pajak.M and Poniskiweski, 2013 were studied about the flexural behaviour of reinforced concrete beam with two different types shape of steel fiber. The result as shown in Figure 2.5.

Based on the authors, both types of steel fiber in the reinforced concrete beam with higher fiber content indicated the higher flexural strength. The shape of steel fiber strongly influences the flexure strengthen concrete. From, the result, the hooked end steel fiber are more effectiveness to improving the flexural strength of the tested beam than the straight ones.The result shows that the strength is 3.4 times higher that the plain concrete, meanwhile for the straight steel fiber about 2.2 times.

Then, the flexural behaviour can be conformed to the Naaman's classification of fiber reinforced concrete (FRC). The deflection hardening response was observed in case of hooked end steel fiber and deflection softening of flexural response for straight steel fiber. According to Naaman, the observed flexural behaviour can be mainly attributed to the length of the fibers and their bond strength. The short strength steel fiber brigde the micro cracks only during strain localization, so this not influences mush the post-peak of the load deflection curve. On the other hand the hooked end provides bridging stress cross the cracks. which are the result of delay the micro cracks. This result improves the toughness of the concrete.

2.4.3 Tensile Strength

Steel fiber also affects tensile strength of concrete. It can proved from the previous studies. Reffering to the findings by S.Shahidan, 2009, the tensile strength of the concrete varies with the volume fraction of the steel fiber in concrete. Nguyen Van, 2010, also have founded that the volume fraction of the steel fiber affect the tensile strength. Referring to the figure 2.6, the aspect ratio of the also effect the tensile strength of concrete. When the aspect ratio was increased, the tensile strength also increased.

Based on Olivito.R.S., 2007, the failure mode is affected by the presence of fibers, while concrete elements usually fails suddenly and break in their middle section, steel fiber reinforced specimen started micro-cracking symmetrically on their side and fiber bridging effect arounded the sudden failure.From that, the steel fiber can improve the tensile strength of the concrete.Then, S.Yazici et.al, 2007 has founded that the tensile strength of SFRC are higher about 11-54% than the control mixture.

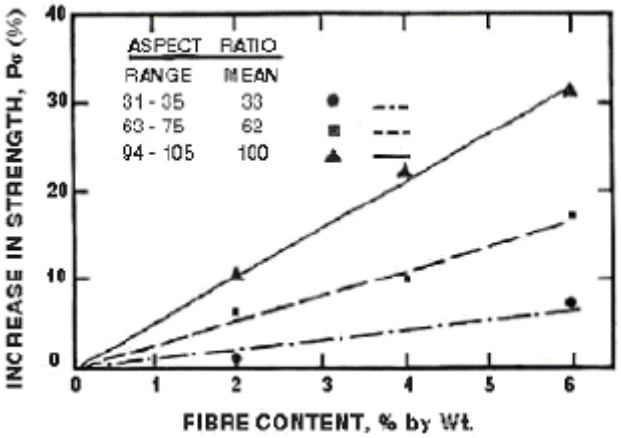

Figure 2.6: Variation of increasing in strength and fibre content

2.5 SUMMARY

After reviewing the previous study about the effect of steel fiber into the concrete and comparing it with plain concrete, the performance of the specimen with addition of steel fiber more better in term of mechanical behaviour than plain concrete. There a variety types of steel fiber and their have own characteristic. Some of the steel fiber may be influences the performance of the concrete but some of it not. From the previous research , there a few authors mentioned there are some factor need to consider for example the volume fraction, shape and aspect ratio of steel fiber will affect the concrete performance. Many researchers have investigate about the effect of volume fraction and different types of shape .There is just few study about the effect of aspect ratio of steel fiber used in structural member like reinforced concrete beam with the different aspect ratio but same length of steel fiber. So, in this study were investigated the effect between the short length with longer of steel fiber but the shape is same.